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Article (Published Version)

frontiers in Sustainable Cities

ORIGINAL RESEARCH
published: 27 May 2020
doi: 10.3389/frsc.2020.00014

Pathways for Sustainable Urban Waste Management and Reduced Environmental Health Risks in India: Winners, Losers, and Alternatives to Waste to Energy in Delhi

Pritpal Randhawa[1], *Fiona Marshall*[2*], *Pravin Kumar Kushwaha*[3,4] *and Pranav Desai*[3,4]

[1] School of Global Affairs, Ambedkar University Delhi, New Delhi, India, [2] Science Policy Research Unit (SPRU), School of Business, Management and Economics, University of Sussex, Brighton, United Kingdom, [3] Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delhi, India, [4] Transdisciplinary Research Cluster on Sustainability Studies, Jawaharlal Nehru University, New Delhi, India

This paper examines the shift toward centralized waste-to-energy (WTE) as a singular solution to Delhi's solid waste crisis and describes a transdisciplinary research process that sought to understand how and why this dominant waste management pathway emerged. It also sought to engage with and facilitate debate on the potential for alternative waste management pathways, which may better address combined environmental and social justice concerns. We explain the emergence of a transforming narrative that reframed waste from a risk to a resource, reflecting and reinforcing the dominant trajectory of socio-technical-ecological change in urban development, and reconfiguring waste related infrastructure to involve public private participation and WTE technology. Drawing on empirical studies, involving local residents, wastepickers associations, NGOs, and government officials, we discuss implications of WTE projects in Delhi. We argue that the current WTE focused approach, without modification, may simply displace health hazards across time, space and social groups and exacerbate social justice concerns. The dominant narrative on waste management priorities appear to make certain health risks protected and recognized whilst others are made invisible. We make the case for possible alternative waste management scenarios, institutional and regulatory arrangements that may better address environmental health and social justice concerns. These are summarized under eight principles for reframing urban waste management policy challenges in the context of sustainable urban development. These principles include a reframing of waste management through a sustainability lens that links currently divergent initiatives on environmental health and social justice. It involves an appreciation of complex socio-material flows of waste, the need to move beyond perspectives of waste management as an environmental policy issue alone, appreciation in policy development that the informal sector will remain a key player despite attempts to formalize waste management and the need to provide incentives for diverse waste management strategies that move beyond the private.

Keywords: solid waste management, social justice, Delhi, sustainable cities, environmental health, transdisciplinary action research, waste to energy (WTE), pathways to sustainability

OPEN ACCESS

Edited by:
Ana E. Escalante, National Autonomous University of Mexico, Mexico

Reviewed by:
Beth Tellman, Columbia University, United States
Ling Shao, China University of Geosciences, China

***Correspondence:**
Fiona Marshall
f.marshall@sussex.ac.uk

Specialty section:
This article was submitted to Urban Resource Management, a section of the journal Frontiers in Sustainable Cities

Received: *20 August 2019*
Accepted: *09 April 2020*
Published: *27 May 2020*

Citation:
Randhawa P, Marshall F, Kushwaha PK and Desai P (2020) Pathways for Sustainable Urban Waste Management and Reduced Environmental Health Risks in India: Winners, Losers, and Alternatives to Waste to Energy in Delhi. Front. Sustain. Cities 2:14. doi: 10.3389/frsc.2020.00014

INTRODUCTION

India faces an urban waste management crisis driven by a combination of increasing municipal solid waste (MSW) generation (the result of a growing population, rapid urbanization and changing consumption patterns associated with economic growth), an inadequate waste management infrastructure and routine lack of compliance with waste management rules. It is estimated that more than 90% of waste in India is dumped in public spaces instead of being sent to properly engineered landfill sites (Kumar et al., 2017). This leads to a host of well-documented environmental and public health impacts and increasing pressure on municipal governments to implement solutions. Recently, waste-to-energy (WTE) technologies have become India's preferred mainstream solution to this waste management crisis, but several WTE projects implemented in Delhi have met with widespread opposition and controversies over environmental impacts and social justice concerns.

Waste-to-energy technologies have been applied extensively in European contexts as part of attempts to find more sustainable ways to deal with urban waste (Dube et al., 2014). However, the operation of such plants depends on a supply of segregated waste that can provide a suitable input to the energy recovery process so it cannot be assumed that any given WTE technology will be workable in a particular context (Joshi and Ahmed, 2016). Indeed, some have argued that incineration based WTE plants in India will be unsuccessful because the calorific value[1] of Indian waste is very low (Sharholy et al., 2008; Talyan et al., 2008). By advocating a recovery-centric approach to municipal solid waste management Narayana (2009) argues that WTE cannot be successful without active citizen participation and careful attention to the proper implementation of regulations. In the context of WTE in Delhi, recent projects have been reported to have been hurriedly implemented without due consideration of the socio-economic and environmental implications (Shah, 2011) or concern for the impact of such projects on the informal livelihoods of wastepickers (Bharati et al., 2012; Schindler et al., 2012).

This paper documents a transdisciplinary action research process in which a group of academic researchers from the UK and India collaborated with local community groups and NGOs to explore how and why WTE came to play such an important role in the government response to the waste crisis, understand the implications of such a response and attempt to promote more socially and environmentally just alternatives. We reflect on this process and its outcomes to consider lessons for the establishment of sustainable urban waste management trajectories which can address environmental and health challenges whilst also addressing social justice concerns.

The action research process was designed according to the STEPS[2] Pathways Approach (Leach et al., 2007, 2010b) which emphasizes the need to understand how competing possibilities for socio-technical and social-ecological system change evolve, interact and shape development trajectories. Drawing on science and technology studies and development studies, it considers how these trajectories of change are shaped by power and politics and co-evolve with the broader, political economic context. The STEPS Center is concerned with the potential to enhance environmental integrity and social justice through sustainable development trajectories that appreciate a diversity of knowledges and innovation options.

The Pathways approach works on the premise that there are multiple, contested "sustainabilities" to be defined and deliberated for particular issues and groups (Leach et al., 2010b). It builds on the concept of framing, defined by Goffman (1974) as a cognitive process by which people make sense of events and experiences, bringing different ideas and interpretations to a problem within a given frame, to the exclusion of others. Leach et al. (2010a) observed that "all framing involves not just choices about which elements to highlight, but also subjective and value judgements." For any given problem, there may be multiple contested framings, all leading to different types of envisaged solutions. These framings are associated with narratives, or stories which define a problem, its consequences and potential solutions in a particular context. The STEPS approach recognizes that "contextually powerful institutions assert particular narratives and framings, so that it is these that become interlocked with strategies of intervention and ensuing pathways of system change, marginalizing alternative narratives in the process." Leach et al. (2010a).

The methodology involves exploration of a diverse range of narratives. Narrative analysis can be used to develop an understanding of the underlying system and problem framings of the stakeholders from which they emerge. In addition, examination of the interplay between narratives can reveal how power is enacted in negotiating potential socio-technical solutions to sustainability challenges, and how narratives come to be reinforced through policy interventions. The pathways approach for action-oriented research seeks to open up dialogue about what exactly is to be sustained by different pathways (or self- reinforcing trajectories of change) within socio-technical-ecological systems and for whom, and to create possibilities to develop alternative social, technological and environmental pathways to sustainability that favor the rights, interests and values of marginalized and excluded people.

In line with these aims, the research was guided by the following research questions:

1. What processes are involved in the prioritization of particular environmental management options and technological interventions for waste management in Indian cities; specifically, what types of issues are formally recognized, which remain unrecognized, how and why?
2. Who gains and who loses from current interventions?
3. If environmental health and social justice are to remain central to waste management strategies - what alternative waste management scenarios, institutional and regulatory arrangements, as well as forms of citizen action, are emergent?

[1]The energy value of a fuel, equal to the heat evolved through complete combustion in oxygen.

[2]The ESRC STEPS (Social, Technological and Environmental Pathways to Sustainability) Centre, steps-centre.org.

The following section of this paper describes the methodology and the specific methods used for this case study. The next three sections (3–5) present empirical results organized around the three research questions. We conclude in section 6 with summaries of the impact of the project and reflections on the lessons learned for achieving socially and environmentally just pathways for sustainable urban waste management.

METHODOLOGY

STEPS methodology can be described in terms of four mutually co-constituting and iterative phases as described by Stirling (2016). Each of these contribute to the process of enhanced appreciation of alternative pathways to sustainability. These four phases are concerned with (1) engaging actors; (2) exploring framings; (3) characterizing dynamics; (4) revealing political actions.

To understand the evolution of dominant and alternative pathways it is important to **engage** with the diversity of **actors** and, together, **explore** the range of narratives and **framings** they represent. Attention to relevant histories, associated networks and prioritization of the views of the most marginal is key. In understanding framings and narratives, it is important to elicit ideas about how sustainability is defined and sought, and how risks (associated with waste management options) are perceived. In the waste management case we were dealing with a highly topical issue in which diverse stakeholders would readily engage. There were strong and polarized views and major contrasts in the values and priorities that that characterized different framings and the narrative of risks and opportunity associated with them. There was a clear dominant pathway of centralized, privatized WTE technologies, but with a number of potential alternatives promoting decentralization, recycling, and greater engagement with the informal sector. To identify the implications of the dominant and alternative pathways it is necessary to **characterize** the **dynamics** of the current trajectory and who wins and loses as it evolves. We were concerned with how and to what extent particular pathways prioritize environmental, health and social justice concerns, and the characteristics that enhance or reduce their ability to do so.

Attention to history remains important through all four phases, to assess how pathways have co-evolved with the wider political economy and come to be shaped and reinforced by local power relations and politics. The goal of **revealing political actions** requires a continual review of key actors and their agency; and learning from previous successful and failed efforts to influence the direction of change in the socio-technical-ecological system. It is necessary to understand what is driving and maintaining particular dominant pathways and what are the key entry points and interventions to facilitate a wider appreciation of alternative more socially and environmentally just pathways.

Each method described below was selected in order to contribute to one or all of the four phases of the pathway analysis, in order to answer our three research questions.

Empirical research for the paper was carried out between 2012 and 2015[3] and involved a mix of ethnographic, participatory appraisal and interviewing techniques alongside reviews of formal academic and gray literature. The research included case study sites in the Indian cities of Ahmedabad, Pune and Delhi. These cities were chosen in order to compare the centralized WTE approach in Delhi with examples of grassroots innovations, and alternative approaches to waste management governance in Pune and Ahmedabad and to provide opportunities for networking and shared learning across the sites. Another key selection factor was the prior long-running involvement of the core research team with communities and other key NGO stakeholders.

Participatory Impact Pathway Analysis (PIPA) workshops provided a platform of shared understanding and purpose which formed the foundation for the other research activities. This method was adapted from Douthwaite et al. (2009), as described in Ely and Oxley (2014) and involved mapping out which stakeholders to engage with and seek to influence during the process of identifying sustainable waste management strategies. Core project partners participated in the first PIPA workshop and then repeated the exercise with external stakeholders both at the start of the research project and on two further occasions as the project evolved and relationships between actors shifted. Following the mapping of actors, discussion was held on the relative influence of difference stakeholders, their potential receptiveness and possible strategies for engaging with them. A series of focus groups and stakeholder workshops and meetings were also organized or co-organized by the research team with local civil society partners and community groups (**Table 1**). Further activities to engage with policy development and or innovations in waste management strategies led by wastepickers associations and others have continued to date.

Forty semi-structured interviews were conducted with stakeholders including government officials representing the central and state governments, local government bodies, waste to energy plant officials, academics, NGO representatives and informal wastepickers and local residents. Standard social science ethical procedures were followed, adhering to the principles of informed consent and confidentiality. Participants were clearly informed that they could withdraw at any time without facing negative repercussions for doing so. In order to acquire specific information on WTE projects in Delhi, applications were filed under the Right to information (RTI) Act. Visits and consultations also took place at WTE sites in Delhi, and a detailed process documentation of informal waste management was carried out in Delhi, Ahmedabad and Pune through the method of shadowing. Shadowing is considered a suitable social science research method for examining day to day spatial-temporal dynamics and social practices (Czarniawska, 2014; McDonald and Simpson, 2014). In our adaptation of this method, the

[3]This empirical research was a part of the ESRC funded collaborative project titled "Pathways to Environmental Health: Moving Between Formality and Informality" involving the ESRC funded STEPS Centre (University of Sussex), Jawaharlal Nehru University (JNU) and Toxics Link, New Delhi along with local community groups and wastepickers associations.

TABLE 1 | Key Outreach and Policy Engagement Activities.

Date	Organized by research team	Attended but not organized by research team
26/3/12	Participatory impact pathways analysis (PIPA) workshop, at JNU, Delhi.	
24/4/12		Joined a protest demonstration and public meeting by workers and residents against WTE incinerator in Ghazipur, Delhi organized by All India Kabadi Mazdoor Mahasangh (AIKMM) and presented about related policy issues.
15/6/12		Participation in photo-exhibition "flowers in the dust" by Kausiki Sarma documenting the lives of wastepickers in Delhi. organized by AMAN Trust.
29/8/12		Joined demonstration and public meeting by workers and residents against WTE incinerator in Rajghat, Delhi organized by AIKMM and shared information on environmental health issues.
19/9/12	Project workshop at JNU, Delhi.	
16/3/13	Session on "pathways to sustainable solid waste management in Delhi" in a daylong workshop on the "problems of waste pickers in Delhi" in collaboration with Lokadhikar and Vidhi Asra motion picture Pvt. Ltd. At World youth center, Delhi.	
1/5/13		Project presentation at Mazdoor Chetna Sabha, jointly organized by AIKMM and national alliance for labor rights, new Seemapuri, Delhi.
24/10/13		Presentation of critique of "draft municipal solid waste management and handling rules 2013" in a workshop on "waste legislation and waste pickers" organized by AIKMM in Delhi.
Nov 2013	Scenario planning workshop with local government officials, academics, residents' welfare associations and NGOs at JNU, Delhi.	
9/1/2014	Workshop on "rethinking municipal solid waste management in Delhi" at the Indian international center, Delhi. with government officials, academics, NGOs, wastepickers associations, and government scientists.	
Feb 2014	Symposium on urbanization and environmental health in Delhi.	

researchers combined non-participant observation with semi-structured interviewing, whilst following individual wastepickers through their daily routine. We also carried out photo mapping; a photographic documentation of routine waste management practices on the ground.

Qualitative data from interviews and secondary sources was analyzed through iterative narrative policy analysis (Roe, 1994), in which themes were identified, documented and reviewed as the research progressed. The first stage of analysis relied on secondary data sources, the narratives outlined in initial scoping interviews and the PIPA exercise. These were then followed up through primary data collection, key informant interviews and workshop sessions.

Formation of the Dominant Narrative Around WTE

Drawing on historical gray and academic literature, **Figure 1** summarizes the evolution of Indian waste management policy in the context of international policy approaches.

The early initiatives on urban waste management in India unfolded around the narrative of waste as a source of risk. This narrative became prominent after the outbreak of the Surat plague in 1994. Shortly afterwards, Almitra Patel, a retired MIT educated engineer, filed a public interest litigation (PIL) before the Supreme Court of India for a violation of Article 21, the right to life and healthy environment (Writ Petition No. 888 of 1996). The Petition argued that "various government

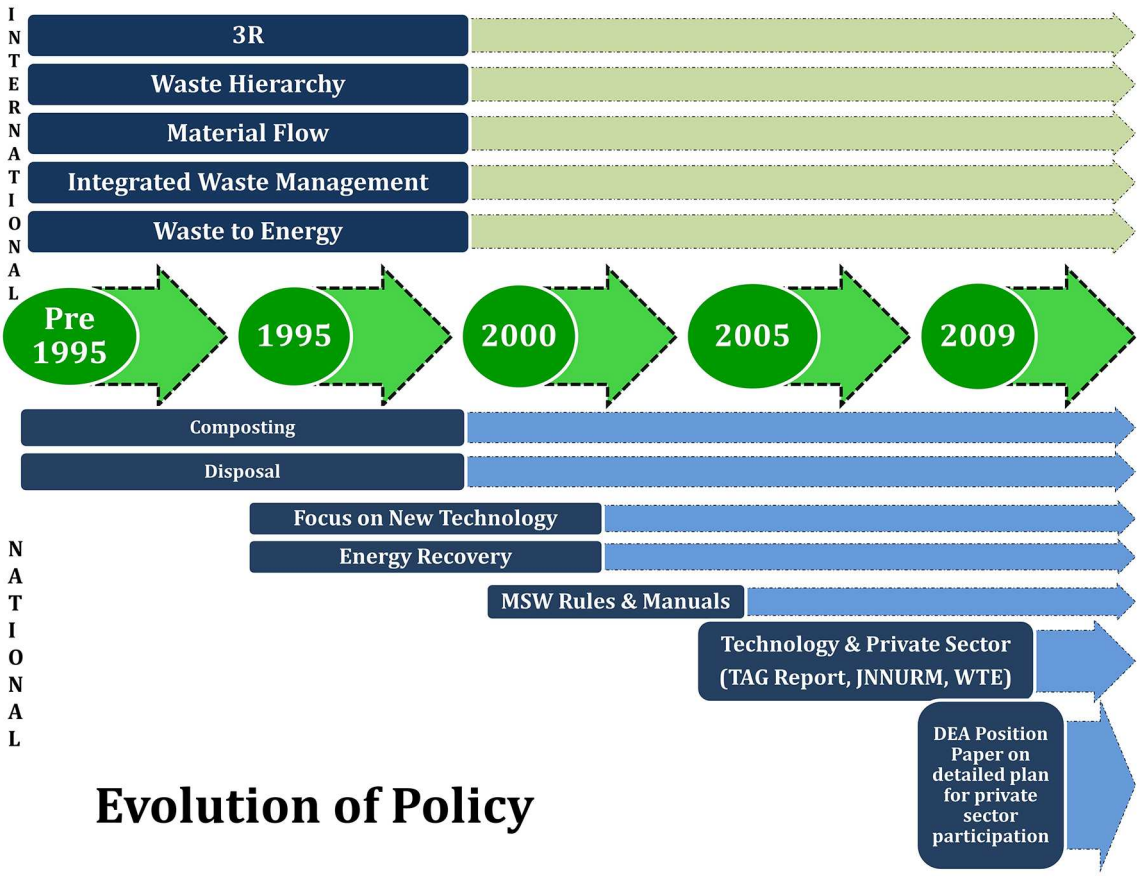

FIGURE 1 | Evolution of waste management policy in India.

agencies had neglected to discharge their constitutional and statutory obligation in relation to the proper collection, handling, transportation and hygienic ultimate disposal or recycling of municipal solid waste" (Rajamani, 2007, p. 297).

In response to Patel's PIL, in 1998, the Asim Burman Committee was formed under the Supreme Court of India to identify deficiencies and make recommendations to improve solid waste management in cities across the country (Burman, 1999). The principal recommendations of this committee were incorporated into the Municipal Solid Waste (MSW Management and Handling) Rules 2,000 notified by the Ministry of Environment and Forest (MOEF) in 2,000. These rules were enacted as one of the many legislations under the Environment Protection Act (EPA) 1986 (MOEF, 2000). The rules outlined the responsibility of multiple authorities dealing with waste within and beyond the city. They provide guidelines for dealing with collection, segregation, storage, treatment and disposal, and also prescribe standards for treatment and disposal of MSW. The rules also recommended that urban local bodies (ULBs) should involve private sector for the management of waste (ibid). Despite the significant role of the informal sector in recycling waste, the rules remained silent on this matter.

While the national level strategy on urban waste management in India was evolving, simultaneously important decisions on waste management were made at international forums. Agenda 21 of the Earth summit (also known as the Rio Summit 1992) proposed major waste related programmes for across the world[4]. Alongside other recommendations, it also suggested that "recovery of secondary materials or energy" from waste could avoid GHG (Greenhouse Gas) emissions in all other sectors of the economy (UNEP, 2010). In this regard, UNFCC adopted the Clean Development Mechanism (CDM) and Joint Implementation (JI) methodologies. In order to achieve these objectives UNEP started various programmes in its member countries. These programmes included Integrated Solid Waste Management (ISWM) based on 3R (reduce, recycle and reuse) approach, Sustainable Consumption and Production, E-waste management, converting waste agriculture biomass and waste plastics into useful energy and/or material resources (ibid).

[4]These programmes include i) waste minimization, ii) maximization of environmentally sound waste reuse and recycling, ii) Promotion of environmentally sound waste disposal and treatment, and iv) Extension of waste service coverage.

It was only after the declaration of the MSW Rules in 2,000 that the narrative of urban municipal waste as a resource of energy generation became prominent. Alongside biomethanation[5], other technological options for generating energy from waste started emerging. In early 2000, the Department of Science and technology (DST) and Technology Information, Forecasting and Assessment Council (TIFAC) initially perfected the refuse derived fuel[6] (RDF) based technology to process municipal solid waste.

The narrative of urban waste as a resource of energy generation gained further momentum in 2005 with the drafting of National Master Plan (NMP) for waste-to-energy under a UNDP/GEF assisted project (NBB, 2005). The NMP recommended recovery of energy from municipal waste through RDF and other options (ibid). In the same year, another government report came out, which discussed various technological options of waste to energy in detail. The report warned, "no waste to energy technology is successful in developing countries, new technologies are coming, after cost benefit analysis these technologies should be adopted" (CPHEEO, 2005). Despite the warning, six WTE projects were planned across Indian cities (including Delhi, Bangalore, Pune and Hyderabad) under the National Programme on Energy Recovery from Urban and Industrial Waste (Dube et al., 2014). The decision to subsidize these projects by the Ministry of Renewable Energy was challenged in the court through PILs. In 2007 in response to the PILs, the court came out with an order that the ministry could subsidize these projects but they should be treated as pilot projects to test the feasibility of waste to energy technologies in India (ibid).

Delhi was the first city to undertake an incineration based WTE project, despite major dissent both within and outside the court. WTE projects based on incineration and refuse derived fuel (RDF) technology started gaining momentum in urban India between 2005 and 2010 with the planning of three projects in Delhi, and expanded in 2015 when the newly elected central government announced four additional WTE projects under the *Swachch Bharat Mission*/Clean India Campaign (PTI, 2015).

Despite the court's jurisdiction of evaluating the pilot WTE projects before making them a popular solution for handling urban waste, several initiatives have been undertaken by various government actors. This has strengthened the narrative of urban waste as a resource of energy generation to gain legitimacy in the policy process. An Indian arm of the Energy Waste Research and Technology Council (WtERT) was co-founded by Columbia University and the National Environment Engineering Research Institute (NEERI) in order to promote WTE technologies in the country (WTER, 2014). Since 2012 WtERT has been active in promoting waste to energy technologies through international conferences and doing certificate courses on WTE technologies etc. In its budget speech of 2013, the then Finance Minister announced a scheme to encourage cities and municipalities to take up WTE projects in Public Private Partnership mode (Pereira, 2013). A task force on waste to energy was constituted to take forward this scheme (Planning Commision, 2014). In 2015 WTE become part of the national level initiative – *Swachch Bharat Mission* (PTI, 2015)[7]. More recently, the new Solid Waste Management Rules 2016 has added a detail section on waste to energy technology (MOEFCC, 2016).

Interviews with key local actors in Delhi identified two distinctive contemporary framings of waste and the waste management system in Delhi which are presented in the **Table 2** in summary and through representative quotes from interviewees.

The narrative around the WTE technology was that it "can kill two birds with one stone" - it can clean the city by scientifically disposing of solid waste and by generating energy it can help reduce the large electricity deficit (Ahluwalia, 2013). This narrative was widely spread by the various proponents of the project. The Chief Engineer of the East Delhi Municipal Corporation (EDMC) propagates it as a more viable option than new landfill sites[8], while the Senior Environmental Engineer of Delhi Pollution Control Committee (DPCC) believes that "it is the future of waste management in India." According to him, due to increasing westernization and changing consumption pattern, there is more use of processed and packaged products. Moisture content in waste is decreasing and calorific value is increasing, which would incinerate better and generate energy[9].

The dominant narrative emphasizes centralization and formal privatization of waste collection and management services through public-private-partnership (PPP) arrangements centered on incineration of waste in WTE plants which simultaneously generate energy and profits while removing the waste problem.

Who Wins and Who Loses From a WTE Pathway

In this section we analyse the trajectory of socio-technical-ecological change and discuss the range of outcomes and impacts on different stakeholders – intended as well as unintended – that emerge as the WTE pathway unfolds. Researchers conducted interviews with officials, waste-picker association members and NGO activists with expert knowledge in order to build a detailed picture of the dynamics of the waste management system in its formal and informal activities. Shadowing with wastepickers gave a unique insight into the informal system of waste management from the perspective of those directly involved.

[5]A method for the treatment of organic wastes through a process of anaerobic digestion generating methane for fuel.

[6]RDF is created by separating out combustible materials from municipal or industrial waste and processing these materials for use in WTE plants, usually by shredding and dehydrating.

[7]Alongside Delhi, the newly elected government announced setting up four more WTE plants under the mission in other Indian cities including Jabalpur, Hyderabad, Nalgonda and Chennai.

[8]There were two sites proposed by the Delhi Development Authority (DDA) for the creation of new landfill sites in Delhi. One was in Jaitpur and another in Madanpur Khadar. While Jaitpur site was discarded due to resistance from the locals, the Madanpur Khadar was also discarded because it falls in the way of an "Air Funnel" (landing zone of flights).

[9]Interview with Senior Environmental Engineer at Delhi Pollution Control Committee (DPCC), date 26-12-2012.

TABLE 2 | Dominant and alternative narratives concerning the problem of solid waste management in Delhi and its proposed solutions.

	Dominant narrative	Alternative narratives
Summary	Centralization and privatization of waste collection and management through incineration turns waste from a problem into a resource for profit.	Waste is already a resource central to the livelihoods of informal wastepickers who provide a service to society and contribute to environmental goals through recycling and waste recovery through composting schemes while WTE creates more problems than it solves.
State actor	"By encouraging WTE, the government can kill two birds with one stone. We can clean our cities by scientifically disposing solid waste and generating electricity and at the same time help reduce the large electricity deficit in the country." Senior official, ICRIER[a]).	
Scientific expert	"With the increasing westernization, WTE plants would be successful in Indian cities because of changing consumption patterns, decreasing moisture content in waste, and increasing calorific value" (senior scientist, DPCC[b]).	"The demerit of such technology is that air pollution can never be avoided even in highly sophisticated plants. The additional cost of the complete pollution control systems is about 30 percent of the power plant cost, which makes it financially unattractive to the already high investment system." (Professor, Dept of Civil Engineering, JMI[c]).
WTE tech firm	"If a single technology is available which handles waste and also gives you power, then I don't think anything else is required." (senior official, jindal ecopolis). "I have been to the okhla plant in Delhi. There is no pollution, and in fact there is no space for the air inside the plant to go outside. You can see the smoke of cigarette but you can't see any smoke in the chimneys." (Director, MNRE[d]).	
NGO		"Why is burning waste the most important thing? We still don't have infrastructure to regulate these toxic emissions, which are critical. Why can't we focus on recycling and composting as a means to tackle the problem of waste management?" (director, toxics link).
Resident		"These plants should not be in the vicinity of any residential colony. It should be far away from any habitation. It is simple—if there is no space in Delhi, then there should not be any WTE plant in the city." (President, Sukhdev Vihar, RWA[e]).
Waste picker		"After all the three WTE plants in Delhi are operational, given their proposed capacity they would require 7,500 MT of waste every day. No recyclables would be left for wastepickers. There would be a major impact on the livelihood of 300,000 informal wastepickers of Delhi." (Chintan, Lokadhikar).

[a] *Indian Council for Research on International Economic Relations.*
[b] *Delhi Pollution Control Committee.*
[c] *Jamia Millia Islamia, Central University.*
[d] *Ministry of New and Renewable Energy.*
[e] *Residents Welfare Association.*

Informal Waste Sector and Privatization

The reconfiguration of waste infrastructure in Delhi started with the process of privatization of collection services. In 2005, the Municipal Corporation of Delhi (MCD) invited private players to engage in the collection and transportation of solid waste (Garg et al., 2007). Before privatization, the informal wastepickers mainly managed door-to-door collection and segregation of recyclables from the waste. The involvement of the private sector in the waste management created major conflict between various government agencies in Delhi and informal wastepickers (Schindler et al., 2012).

It was assumed that bringing in the private sector would improve management efficiency issues, which the informal sector is arguably challenged with, as well as bring in better accountability than the municipal systems offer. Our fieldwork in Delhi shows that despite contracting the private sector for collection and transportation of waste, the informal sector continues to be deeply involved in the process, demonstrating the futility of trying to ignore their role. More than 50 per cent of primary collection is still done by the informal sector. There are many areas in which, either owing to space or manpower constraints, the private sector mechanisms for waste collection

FIGURE 2 | Waste pickers go door to door collecting household waste, usually without pay.

FIGURE 3 | Others waste pickers perform roadside collections.

FIGURE 4 | Collected waste is transported to "khatta" (community bins).

and segregation do not work and are subsequently dependent totally on the informal sector[10].

According to the study done by the Institute of Human Development, there are 54 kinds of recyclable items in urban waste which are segregated by the informal waste pickers (Bhargava et al., 2012). According to the official figures, the informal wastepickers reduce the waste disposal load by 1,500 MT every day in Delhi. However, this figure is contested by many wastepickers associations, who believe that the figure is much higher. Official data suggests that during 2002-03, waste trading added a social value of Rs. 358.7 crore – or approximately 73.8 million USD – in Delhi (Khandelwal, 2012). The study shows that wastepickers also contribute in the reduction of GHG emission. A study estimates that informal wastepickers in Delhi prevent approximately 932,133 tons of GHG emission every year (Chintan, 2009). These two figures reveal that informal wastepickers play an important role in handling urban waste and preventing GHG emission, hence they should be formally involved in the waste management process keeping in view the challenges of occupational and environmental health related to their work (Wilson et al., 2006; Chikarmane, 2012).

The results from the shadowing exercises with wastepickers reveal more clearly the interactions between informal and formal waste systems through the daily routine of wastepickers in Delhi. The photographs and captions in **Figures 2**–**8** provide a narrative of this daily routine.

It was clear from the shadowing exercises and key interviews with representatives of wastepicker organizations that the informal sector continues to play an important role in the waste management system alongside formal private companies. At the same time, their role in the waste management system provides a source of livelihood that is vital to thousands of the poorest residents of Delhi. Until waste was recast as an energy resource in India, it was a matter of "negative environmental change" (Heynen et al., 2006). With little formal interest in resources from waste, all the recyclables in the waste stream belonged to the informal wastepicker becoming part of a complex recycling chain, and a major source of livelihoods. The shift in the narrative of urban waste from a source of risk to a resource for energy generation results in the same recyclable waste potentially being sought by WTE plants in order to produce energy, particularly as they are incentivized by the volume of waste they process. This in turn may have serious consequences for the livelihoods of wastepickers and implications for environmental outcomes as different wastes are processed in new ways.

Social Justice Outcomes of WTE

According to the government figures, Delhi generates 8,360 Metric Tons (MT) of municipal waste everyday which comprises

[10]Process documentation of collection and segregation by the informal waste pickers in Rohini Sec X, New Delhi.

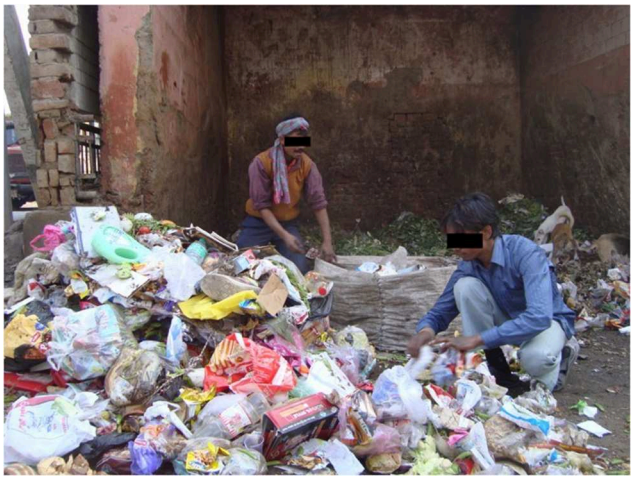

FIGURE 5 | At the khatta, waste is segregated and recyclables are collected.

FIGURE 6 | The recyclable waste is transported by waste pickers to their "jhuggies" (huts).

FIGURE 7 | The recycled waste is collected and stored at the waste pickers' jhuggies where it is further segregated into 54 different types of recyclable.

FIGURE 8 | Scrap dealers buy recyclables from the waste pickers and sell them on through the recycling industry.

of both biodegradable and non-biodegradable waste[11] (GNCTD, 2015). Once all the three WTE plants are operational in Delhi, they would require approximately 6,250 MT of waste per day to produce the projected amount of energy, leaving about 2,110 MT of biodegradable waste and inert material. If the WTE projects manage to do that then it would have significant impact on the informal waste-pickers. A study carried out after 9 months of operation of Okhla WTE plant shows that there is a significant decrease in the numbers of waste workers in the Okhla landfill sites, as recyclables are diverted to the WTE plant. The livelihoods of wastepickers were already threatened after door-to-door collection was handed over to the private companies (Schindler et al., 2012), and WTE projects have further intensified the threat of loss of livelihood. It is estimated that the livelihoods of approximately 300,000 informal waste workers would be lost after all the three WTE plants are operational in Delhi (Bharati et al., 2012).

Environmental Outcomes of WTE

Despite being claimed as a clean technology by its proponents (DPCC, 2006; IL&FS, 2008), WTE in Delhi is surrounded by controversy in terms of environmental health. The controversy is mainly about the emissions from the WTE plant, the cost of controlling them and the lack of effective regulation. According to an expert in Delhi, the additional cost of the complete pollution control systems is about 30 percent of the power plant cost, which makes it financially unattractive to the already high investment system. The pollution is due to particulate matter, CO2, SO2,

[11] Despite population growth and increase in the consumption, this official figure has remained unchanged in the past one decade.

NOx, dioxin, and furans. The remaining ash after incineration also contains toxic elements such as arsenic, cadmium, lead and mercury. Treating ash for the pollutant is another costly affair[12]. Other published studies, focusing on WTE technology and emissions, support this argument (Akella et al., 2009; Narayana, 2009; Toller et al., 2009; Shah, 2011).

Lack of regulatory control was another issue that was raised in interviews for this study. For example, according to a DPCC official, the technology used in the Okhla plant is not RDF as specified in the Detailed Project Report (DPR) (CPCB, 2011). It is actually incineration-based technology, where waste is fed directly into the boilers[13]. An evaluation committee constituted by the Central Pollution Control Board (CPCB) has found violation of emission standards by the Okhla plant. According to the committee report, there is a deviation from the technology outlined in the Detailed Project Report and Environmental Impact Assessment reports submitted by the contractors of the project[14]. The report suggests that the modified technology has a risk of producing emissions having severe environmental implications (CPCB, 2011). Another report by a six member committee headed by CPCB on the direction of National Green Tribunal (NGT) in response to a PIL (W.P (C)No.9901, 2009) filed by the people living in the vicinity of the plant shows that the levels of dioxins and furans in the vicinity of the plant were several times higher than the permissible limits[15]. WTE is often presented as a clean technology which will address the considerable environmental concerns associated with older landfill sites. However, it can be argued that, without effective regulation of emissions the incineration of waste may simply redirect the flows of environmental risk; for example, reducing the risk of pollutants leaching into the water while increasing toxic gaseous emissions. The official narrative emphasizes the potential to address certain health hazards whilst making others invisible. Whilst attempting to reduce the environmental and health hazards associated with land fill sites, new centralized technologies are associated with new types of extremely toxic emissions being produced and a lack of proper regulatory mechanisms for controlling them. As one senior environmental NGO representative stated "Why is burning waste the most important thing? We still don't have infrastructure to regulate these toxic emissions, which are critical. Why can't we focus on recycling and composting as a means to tackle the problem of waste management?"

The location of the Okhla plant is in the midst of a densely populated region of South Delhi. The pollution from the plant may have adverse environmental health impacts on people across social strata. Several middle and lower-middle class colonies are located in the vicinity of the plant[16]. Many big private hospitals such as Holy Family, Fortis-Escorts, and Apollo Indraprastha are in close proximity to the plant as well. Two crucial wildlife sanctuaries, the Okhla Bird Sanctuary and the Assola Wildlife Sanctuary, fall within 10 km radius of the plant site (Shah, 2011). The residents of Sukhdev Vihar have filed a PIL against the plant based on environmental health impacts of incineration-based technology and lack of an effective EIA of the plant (W.P.(C)No.9901). The residents in the vicinity of the plant have started complaining about different kinds of health problems. Frequent problems of headache, irritation in eyes, sleeplessness, breathlessness etc. due to the smoke coming out from the plant were reported during the fieldwork. The Resident Welfare Association president expressed concern stating, "these are the common health problems, which we are facing currently but I am sure that if the situation with the WTE plant continues then there are going to be serious health issues in this area."[17]

Environmental health risks are distributed throughout the waste chain in diverse forms such as air and groundwater pollution and occupational hazards for wastepickers. However, the implementation of WTE addresses only the direct impacts of waste accumulation on middle-class neighborhoods and land-fill sites by providing a means of removing waste from residential areas and redirecting it from land-fill. This creates a new potential health hazard in other neighborhoods near WTE plants in terms of air pollution from incineration and leaves the health risk associated with the informal waste sector invisible. On the other hand, while informal wastepickers add a social value to Delhi's economy, privatization of waste management through WTE creates new conflicts with the informal sector which could be mitigated by alternative hybrid arrangements and partnerships.

What Alternatives Are Possible?

Focus groups and stakeholder workshops provided the opportunity to explore past experience and future opportunities for political actions to support alternative pathways of urban waste management. The research team sought to reveal political actions to support alternative waste management pathways on two key levels: top-down policy and bottom-up innovations in waste management practices. These actions were guided by eight principles for reframing urban waste management through a sustainability lens, which were distilled throughout the research process in dialogue with multiple stakeholders. We summarize the eight principles as follows:

1. Waste is not only an environmental policy issue but also touches issues of public health and the livelihoods of informal sector workers.
2. Waste flows are far more complex than is acknowledged in the formal assessments by official agencies.
3. Environmental health and social justice challenges are distributed throughout the waste chain. It is important

[12]Interview with the Faculty member of Department of Civil Engineering, Jamia Milia Islamia, Date 12 June 2013; Interview with Professor from Department of Biochemical and Biotechnology Engineering, Indian Institute of Technology, Delhi, 25 March 2013.

[13]Interview with Senior Environmental Engineer, Delhi Pollution Control Committee, 26 December 2012.

[14]Initially proposed WTE plant was based on MSW > MSW segregation > RDF plant + Bio-methanation plant > RDF Bioler + Electricity. This has been modified/simplified to; MSW > MSW segregation > Direct feed of MSW in WTE Boiler > Electricity.

[15]Interview with President, Sukhdev Vihar Resident Welfare Association, Date: 13 June 2013.

[16]Some of these colonies include Sukhdev Vihar, Haji Colony, Gaffar Manzil, Jasola Vihar, Noor Nagar, Masih Garh, Johri Farms, and Sarita Vihar.

[17]Interview with President, Sukhdev Vihar Resident Welfare Association, Date: 13 June 2013.

to recognize the ways that implementation of centralized technologies can exacerbate these issues.
4. Privatization does not replace the informal sector but emerges alongside it, generating new conflicts between formal and informal which can negatively impact livelihoods of the poor. Nevertheless, there are opportunities (and successful examples) to constructively link formal and informal activities.
5. Multiple options for decentralization are possible alongside centralized approaches (e.g., waste collection/decentralized bio-methanation, joining up community level composting with support for replacing chemical fertilizers with organic fertilizers in local agriculture).
6. Incentive structures could support more sustainable options - they currently only support private sector stakeholders and technocratic solutions.
7. Multiple schemes for people's participation in urban development decision-making have failed. however, there remain possibilities for constructive engagements in policymaking, planning, implementation and review of waste management projects.
8. Environmental health and social justice movements offer key insights into alternative waste management pathways. There are emergent opportunities to strengthen and develop alliances that reach across sectors, class and complementary agendas to build momentum behind alternative sustainable waste management strategies.

The research team engaged with policy-makers, private companies and wastepickers organizations to explore ways in which these principles could be implemented through policy and at the level of day-to-day practice.

Policy

Throughout the project, team members engaged with the wider public, government departments and local actors. A symposium was organized in Delhi on 16th March 2013 in collaboration with the Lokhadikar wastepickers association (project team members). This was a large public event involving government officials, researchers and wastepickers focusing on the lives of wastepickers and their contribution to the city. Following up from the symposium, the team engaged increasingly with the Ministry of Environment, Forests and Climate Change which was overseeing a key piece of waste management legislation (Municipal Waste Management Rules 2000).

This legislation outlines the responsibilities for waste management of local authorities and provides guidelines for how waste is to be managed. It was published for public consultation in October 2013 and a Kamataka High Court ordered that the rules be stayed for being too "regressive." Simultaneously, several groups also raised objections against the rules. The project team's NGO collaborator, Toxics Link, submitted formal objections drawing on the research findings and highlighted the ways in which the rules overlooked opportunities for sustainable waste management strategies. This led to a policy stakeholder forum organized by the project team in January 2014 attended by senior officials from the Ministry of Environment and Forests, the Ministry of Urban Development and the Central Pollution Control Board and a range of other stakeholders representing academic institutions, NGOs and wastepicker associations. One of the research team was subsequently invited to contribute to a government committee responsible for redrafting the rules.

This formal influence on policy was reinforced through a widely viewed interview with one of the project team members on a popular Indian show, Satyamev Jayate, in March 2014. Further, in May 2015 the project team published a policy brief at a high-profile event in Delhi involving government officials, and representatives from wastepickers associations, NGOs, industry and resident welfare associations which was reported in the national press. The policy brief outlined eight principles for rethinking urban waste management through a sustainability lens which were developed in collaboration with the range of actors engaged throughout the research process and was a timely reference for the redrafting of the MSW guidelines published in amended form in May 2015.

Practice

In addition to the formal influence on policy, the research team identified an opportunity for reframing waste management at the level of the day-to-day formal and informal practices of actors engaged directly in waste collection and processing. An alternative vision of urban waste management was identified through interviews and focus groups with wastepickers and NGOs which proposed decentralization of waste management systems to focus more on recycling with a central role for the informal sector and more localized community composting initiatives to handle organic wastes. The example of Pune City was cited as inspiration for such a potential future alternative to the dominant pathway.

The SWaCH initiative in Pune (since 2007) involves an alliance of the Pune Municipal Corporation, citizen and the wastepickers. The citizens are required to do a mandatory at-source segregation of dry and wet waste, while the wastepickers are responsible for door-to-door collection, segregation and decentralized processing (composting) and recycling of waste[18]. The *Parisar Vikas* programme initiated by the Stree Mukti Sanghtana (SMS) in Mumbai with the cooperation of the Municipal Corporation of Greater Mumbai (MCGM) in 1998 is another such example. Under this programme decentralized composting and bio-methanation are being run successfully at many places in 13 wards of Mumbai, including Tata Institute of Social Sciences (TISS), Tata Institute of Fundamental Research (TIFR), various housing societies etc. (StreeMuktiSanghatana, 2014). In a similar vein, Self-Employed Women's Association (SEWA) in Ahmedabad has organized 49,240 wastepickers and cleaners in Ahmedabad[19]. Despite privatization of primary and secondary collection in the city, SEWA has been organizing women wastepickers and has constituted Gitanjali Cooperative Society of wastepickers, which has a stationary unit involved

[18]Interview with Manager, Citizens Outreach at SWaCH on 16 October, 2013, Pune.

[19]Interview with Meenakshiben from SEWA, Ahmadabad on 28 October 2013.

in making various products out of recycled waste. These include notebooks, notepads, diaries, pen, pen stand, paper bags innovative jewelery etc. In addition to wages, they also gain other social benefits because of their association with the cooperative[20].

Through regular interactions between research team members and wastepickers unions and NGOs facilitated shared learning from the research studies in Pune and Ahmedabad which provided inspiration for Delhi's Lokadhikar wastepickers organization to sign a formal contract with a private company to segregate waste for 45 community bins in Rohini Zone. This provides a practical example of principle 4 by demonstrating how informal and formal private sectors can form new synergies which support informal livelihoods. These interactions have also led to a change in perspective among representatives of wastepicker groups (such as AIKMM) from seeing waste management as a narrow labor rights issue to a more integrated vision of the contribution of wastepickers to a range of social and environmental benefits and the potential for linking informal and formal waste management systems. This shared learning has also led to grassroots initiatives to implement decentralized composing technologies through new partnerships between informal waste workers, municipal bodies and resident welfare associations.

Interactions with various stakeholders highlighted the need to consider a mix of scale in the treatment of urban waste. Some waste streams like bio-medical waste, e-waste or plastic waste, construction and demolition waste need technical interventions which work best at larger scale owing to the kind of technologies needed as well as the regulation required to keep their operations within discharge and emission limits (Agarwal et al., 2015). However, degradable urban waste, such as is generated in households, institutions and markets places, by its very nature can be processed using technologies such as composting and bio-methanation, which can be applied at local levels.

Through interviews and focus groups it also became clear that informal wastepickers were mainly concerned with the issue of social justice which they feel is exacerbated greatly by waste management strategies dominated by WTE. While for middle-class residents, issues of environmental health were more important, related to emissions from the WTE plants. In Delhi, despite diverse concerns, both informal wastepickers and middle-class residents came together on a common platform to protest against the construction of specific WTE plants. Several protest marches were organized under the banner of that platform[21] (Krishna, 2011). Such a mobilization is unique in its nature where both set of actors – motivated by different concerns have come together on a single platform. Undoubtedly it is an opportunist alliance, but such an alliance also illustrates that sustainable waste management strategies will require effective engagement well-beyond traditional environmental policy actors, and that there is further potential to influence waste management trajectories by highlighting synergies between environmental, health and social justice perspectives.

CONCLUSIONS AND REFLECTIONS ON IMPACTS

The evidence presented in this paper reveals that waste flows are far more complex than assumed by the technological solution that is proposed. The informal sector plays a significant role throughout the network of waste collection and processing yet is unrecognized in waste management policy. Large-scale privatization and formalization of urban waste infrastructure does not replace this informal sector but emerges alongside it generating new conflicts while opportunities for cooperation are overlooked. Public participation in urban development decisions has been obstructed leading to an obstruction of clear opportunities for constructive engagements with diverse stakeholders in policymaking, planning and implementation.

Analysis of the unfolding dominant pathway reveals that environmental health and social justice challenges are distributed throughout the waste chain and some have been exacerbated by the drive for a centralized WTE approach to municipal waste management. While incentive structures support powerful private sector stakeholders and large-scale technological solutions, possible alternative approaches to waste management are neglected and environmental health and social justice outcomes will deteriorate. In short, the dominant pathway may be sowing the seeds for its own failure as political opposition among the public broadens and grows stronger.

The present waste management strategies in India are being made on the basis of a standardized model of flows of waste in cities that incompletely reflects the situation on the ground in a number of important ways. Debates occurring at different institutional scales including through international networks and national institutions are disparate and disconnected, neglecting critical aspects of social and environmental justice. As a result, there is a failure in addressing urban waste management challenges related to environment, health and social justice. For example, in most of the policy articulations, the removal of waste to other parts of the city (in landfills), or its incineration, is seen to address the problem (MOEF, 2000; CPHEEO, 2005; MOEFCC, 2016). The deeper examination of waste flows, and associated risks reveals that the adverse effects of waste may simply be being moved around the city to impact on different locations and social groups. In terms of environmental hazards incineration may merely move toxic pollutants from the ground to the air and generate ash with adverse health impacts (Agarwal et al., 2015).

The dominant narrative formed around WTE as a total solution to the waste crisis by framing the crisis as an issue of finding the most efficient way of removing harmful waste from the city, to which WTE appeared the perfect solution. This narrative transformed waste from a risk into a resource

[20]Interview with Yashodaben at Geetanjali Co-operative Recycling Unit, Ahmadabad on 28 October 2013.

[21]For more information on numbers of protest that happened against the plant, please check http://www.toxicswatch.org/.

for WTE plants while ignoring the role that waste already played as a resource in the informal livelihoods of wastepickers. It also cast the environmental health hazards associated with waste in narrow terms as controllable threats of pollution from unprocessed waste. This ignored the multiple emergent hazards that are associated with the complex waste management system that incorporates formal and informal sectors. While seeking to solve one environmental health problem, the newly built WTE infrastructure simply shifted the shifted the hazard to one of airborne pollutants, the consequences of which are still emerging.

In response to this analysis and in collaboration with strategic stakeholders, the research team adopted two direct routes for impact, at the level of policy and practice. By engaging with the live debates and emerging policies in Delhi, the research team found opportunities to contribute to the formal policy process around urban waste management. The amended MSW rules published in 2015 reflected many of the eight principles for reframing waste management outlined above. The rules moved beyond an "environmental policy only" perspective on urban waste (principle 1) and included many new stakeholders in the management of urban waste (clause 5 MSW rules 2016). The role of the informal sector was recognized in clause 11 and 15c, reflecting principle 4. There was greater recognition of decentralized technologies such as biomethanation and composting as methods for treating organic wastes alongside centralized WTE solutions (principle 5) with the explicit requirement that communities should be involved in waste management and promotion of decentralized processing alongside support for agricultural use of fertilizers produced from organic wastes [clause 4 (7) and 8].

At the level of practice, a new model of cooperation between formal private sector and informal wastepickers groups began to take shape and continued to evolve beyond the end of the formal research project. The activities with local informal actors in Pune and Ahmedabad supported engagement with wastepickers associations in Delhi and provided the opportunity to explore a wider set of framings and potential pathways of change.

The signing of a contract between Lokadhikar and a private waste management company and the promotion of decentralized composting schemes by the All India Kabadi Mazdoor Mahasagnh both represent a reframing of waste management on the part of wastepickers organizations and waste management companies.

This kind of combination of top-down and bottom-up reframing of waste management points to an alternative pathway of socio-technical-ecological change in waste systems that avoids lock-in to a single top-down technology driven solution. The examples of alternative waste management practices illustrate the range of options for a more sustainable pathway of waste management that combines decentralization alongside centralized approaches, through cooperation between formal and informal waste infrastructures. In addition, the strengthening alliance of environmental health and social justice movements reveals an opportunity to foster such alternative pathways in Delhi's municipal solid waste management. However, there is still much to be learnt and shared from transformative experiments in solid waste management and issues related to scalability and institutionalization.

This research also provides lessons for the role of transdisciplinary research (TDR) in urban sustainability transformations. Recent scholarship emphasizes the key role of transdisciplinary research to co-produce knowledge that challenges dominant narratives and creates new networks that involve and empower marginalized actors (Marshall et al., 2018; Iwaniec et al., 2019). We have shown how the STEPS Pathways approach can be applied in the mode of scholar-activists to empower marginalized actors to reframe debates on sustainable urban waste management challenges and bring social justice and environmental concerns together into a constructive platform. A key element in this process was the combination of methods to analyse the diverse underlying framings of the waste management challenge and the interplay between conflicting narratives, together with empirical studies of the material implications of existing policy trajectories for diverse interest groups.

Through working closely together with long standing policy advocacy groups, local and national NGOS, the academic strands of the work became fully embedded in a process which was intended to contribute to transformative change. This project exemplifies the need to spend significant time and energy on alliance building before and throughout action research initiatives of this type. In order to be influential these alliances need to be agile enough to respond to the changing political context and to evolve diverse pathways to impact at the level of formal policy and grass-roots changes in practices. In these ways the project contributed to two complementary elements of "transformative space making" (Marshall et al., 2018) in the Delhi's waste management knowledge system. First, by engaging with various policy processes, the project built the legitimacy of knowledges of the poor and informal sectors and helped to re-frame the narrative to reflect their perspectives. Second, by fostering new alliances and working with NGOs the research team helped to build readiness among poor and pro-poor actors to engage in opportunities for change in policy and practice.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable data included in this article.

AUTHOR CONTRIBUTIONS

PR carried out the majority of the field work and was responsible for writing much of a first draft of the manuscript in collaboration with FM, PK, and PD. FM was responsible for leading the

research study, providing academic inputs throughout the planning, implementation and data analysis, and producing the revised draft of the manuscript. PK was involved in carrying out some of the field work for the study and drafted a portion of the first draft of the manuscript. PD was the Delhi based lead for the study. He provided inputs and advice to guide research activities in Delhi and commented on drafts of the manuscript.

ACKNOWLEDGMENTS

This paper is an output from the research project entitled Pathways of Environmental Health in Transitional Spaces: Moving between Formality and Informality an activity of the Social, Technological and Environmental Pathways to Sustainability (STEPS Centre) (ES/I021620/1), supported by the Economic and Social Research Council (ESRC). The research for this paper was jointly carried out by FM at the University of Sussex (UK) with a team from Toxics Link (India) and Jawaharlal Nehru University (India) including Ravi Agarwal, Satish Sinha, Piyush Mohapatra, PD, PR (presently at Ambedkar University Delhi) and PK. We are indebted to all the interviewees in Delhi, Mumbai, Pune and Ahmedabad for giving us their valuable time, and sharing information and experience on the issue. We are particularly grateful to Dharmendra Yadav (Lok Adhikar) for helping the research team to undertake fieldwork. We are thankful to Vimal Monga (Skuhdev Vihar Resident Welfare Association), Asha Arora (Anti Incinerator Committee, Sukhdev Vihar), SEWA (Self Employed Women's Association), Kagad Kach Patra kashtakari Panchayat (KKPKP) and Stree Mukti Sanghthan for generously spending a considerable amount of time with the research team and for introducing us to residents in the vicinity of Okhla WTE plant, and informal waste pickers in Ahmedabad, Pune and Mumbai. Also, we extend our gratitude to all the government officials and academics who took out time from their busy schedule to share their perspective. Finally, we would like to thank the referees for their helpful comments on the earlier version of this paper.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.